Technical Report 492

AD A100867

EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON ACQUISITION AND RETENTION OF MOVEMENT END-LOCATION

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U. S. Army
Research Institute for the Behavioral and Social Sciences

November 1980

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
(14) ARI-TR-
Technical Report 492

2. GOVT ACCESSION NO.
AD-A100

3. RECIPIENT'S CATALOG NUMBER
867

4. TITLE (and Subtitle)
EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON ACQUISITION AND RETENTION OF MOVEMENT END-LOCATION.

5. TYPE OF REPORT & PERIOD COVERED
(9) Final rept.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Joseph D. Hagman

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
US Army Research Institute for the Behavioral & Social Sciences, PERI-II
5001 Eisenhower Avenue, Alexandria, VA 22333

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
2T161101A91B

11. CONTROLLING OFFICE NAME AND ADDRESS
Deputy Chief of Staff for Personnel
Washington, DC 20310

12. REPORT DATE
November 1980

13. NUMBER OF PAGES
22

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(12) 31

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Training	Repetition
Motor Skills	Presentation Trials
Learning	Test Trials
Retention	Linear Positioning

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The experiment examined relative effects of three training methods on acquisition and retention of movement end-location information. Three groups of 15 governmental employees performed three training trial cycles consisting of six trials each. Training methods differed in emphasis on presentation (p) and test (t) trials performed during each cycle. For one group, a cycle consisted of three p- and three t-trials administered in alternation. For another group, the first five trials of each cycle were p-trials and the sixth was a t-trial.

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

408010

For the last group, the first trial was a p-trial and the next five were t-trials. Group acquisition performance was compared at the last trial of each training cycle, while retention was compared 3 minutes and 24 hours after acquisition.

Absolute (unsigned) error revealed that final acquisition was better when training emphasized p-trial repetition or p- and t-trial alternation within cycles. Long-term retention was better when training emphasized t-trial repetition. It was concluded that testing is an effective way to improve long-term retention of motor skill and that improvements could be realized by changing the emphasis of training from presentation to testing. This could be done without added training resource expenditures.

Technical Report 492

EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON ACQUISITION AND RETENTION OF MOVEMENT END-LOCATION

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Office, Deputy Chief of Staff for Personnel
Department of the Army

November 1980

Army Project Number
2T161101A91B

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FOREWORD

The Training Technical Area of the Army Research Institute for the Behavioral and Social Sciences (ARI) conducts research in support of the systems engineering concept of training. A major objective of the research is to develop the fundamental data and technology necessary to improve training procedures and enhance individual job performance.

This report examines the relative effects of different training methods on motor skill performance and is one of a series on specific topics in the area of skill acquisition and retention. In response to requirements by the Deputy Chief of Staff for Training of the Army Training and Doctrine Command (TRADOC), the long-term research goal is to develop methods for predicting proficiency loss for all types of skills and for determining effective training procedures for reducing this loss. The present work represents a basic research effort completed by ARI personnel under Army Project 2T161101A91B.

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EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON ACQUISITION AND RETENTION OF MOVEMENT END-LOCATION

BRIEF

Requirement:

To evaluate the relative acquisition and retention effects of three motor task training methods that differ in their emphasis on presentation (study) and test (recall) trials.

Procedure:

Three groups of 15 participants performed 18 training trials on a simple linear positioning motor task. Training trials were divided into three cycles of six trials each, containing both presentation and test trials. During presentation trials, participants studied movement end-location by moving a sliding mechanism along a linear track until contacting a mechanical stop that defined the end-location to be learned. During test trials, they tried to recall the end-location by positioning the slide without the aid of the stop.

The experiment contained an acquisition and a retention segment. During the acquisition segment the sequence of presentation and test trials performed within cycles differed for each training method group. For the STANDARD group, a cycle consisted of three presentation and three test trials administered in alternation. For the PRESENTATION group, the first five trials of each cycle were presentation trials and the sixth was a test trial. For the TEST group, the first trial was a presentation trial and the next five were test trials. During the retention segment, all participants performed a single test trial at both 3 minutes and 24 hours after the last training trial.

Findings:

The three training methods had different effects on acquisition and retention. Absolute (unsigned) error revealed that final acquisition performance was best when training emphasized either repeated presentation (PRESENTATION group) or alternation of presentation and testing (STANDARD group). Repeated testing during training (TEST group), produced superior long-term retention.

Utilization of Findings:

Testing during training is an effective way to improve long-term retention of motor skill. This improvement can be achieved by changing the emphasis of training from presentation to testing without the need

for additional training resources. If instead of long-term retention, the goal of training is rapid acquisition, training which emphasizes either repeated presentation or alternation of presentation and testing is most effective. Additional research is needed to determine if these laboratory results generalize to military-related motor skills.

EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON ACQUISITION AND RETENTION OF MOVEMENT FND-LOCATION

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INTRODUCTION

A long-term goal of the Army is the development of effective methods for training Army-related skills. Of particular interest is the question of which training methods promote the highest levels of skill acquisition and retention. Much of the theoretical and empirical information relating to this question has originated from basic research experiments investigating verbal and motor task learning. In these experiments, training has involved the execution of both presentation (p) and test (t) trials. During p-trials, participants study information to be learned, whereas during t-trials they attempt to recall it from memory. The number and sequential arrangement of p- and t-trials performed during training has depended on the particular method adopted. The standard training method has involved the alternation of p- and t-trials (e.g., Tulving, 1967; Wrisberg & Schmidt, 1975) but other methods that emphasize either p- or t-trial repetition have also been used (Adams & Dijkstra, 1966; Bilodeau & Bilodeau, 1958; Hogan & Kintsch, 1971; Wenger, Thompson & Bartling, 1980).

The Army's question of which training methods promote the best acquisition and retention is difficult to answer because relevant theories make conflicting predictions about the relative contribution of p- and t-trials to the learning process. For example, from a traditional learning theory viewpoint where p-trials are seen as having a beneficial effect similar to reinforcement, training methods which repeat p-trials are predicted to be more effective than those which repeat t-trials. Repetition of t-trials reduces the number of reinforcement opportunities, and therefore, should retard both acquisition and retention. From a contemporary cognitive viewpoint, information processing activities such as memory retrieval and internal generation of to-be-learned items are considered important aspects of acquisition and retention (Bjork, 1975; Dosher & Russo, 1976; Graf, 1980; Slamecka & Graf, 1978). Because t-trials provide an opportunity to practice these activities on information studied during p-trials, training methods which repeat t-trials should also enhance acquisition and retention.

Examination of the empirical evidence related to the issue of which training methods are most effective also reveals inconsistencies when both motor and verbal task learning are considered. Most of this evidence has come from research on verbal task learning. In general, investigators have found that p-trial repetition during training produces superior acquisition (Hogan & Kintsch, 1971; Thompson, Wenger & Bartling, 1978, Exp III), whereas t-trial repetition during training produces superior retention (Allen, Mahler & Estes, 1969; Hogan & Kintsch, 1971; Raye, Johnson & Taylor, 1980; Rosner, 1970; Thompson, et. al., 1978. Exp III).

The pattern of results for motor task learning, on the other hand, has been somewhat different. Generally, p-trial repetition during training has enhanced both acquisition (Holding & Macrae, 1964) and retention (Adams & Dijkstra, 1966), whereas t-trial repetition has had little beneficial effect on either process. Although both subjective recall consistency and error detection ability have developed as a function of repeated t-trials (Newell, 1974; Seashore & Bevelas, 1941), movement accuracy has not been found to improve (Holding & Macrae, 1967; Newell, 1976; Exp I; Thorndike, 1927) except after considerable prior t-trial repetition (Newell, 1976, Exp I and III). In fact, accuracy typically has decreased during both acquisition and retention when t-trials have been repeated during training (Bilodeau & Bilodeau, 1958; Duffy, Montague & Laabs, 1975). Thus, training methods stressing p-trial repetition have had consistent beneficial effects on both motor and verbal task performance especially at acquisition. In contrast, methods stressing t-trial repetition have positively affected verbal task retention but have negatively affected both motor task acquisition and retention.

Specific reasons for the differential effect of t-trial repetition on verbal and motor task performance are difficult to pinpoint because of the many differences that exist between the two areas of research. One suggested reason, however, centers around the difference in information processing activity required of persons at p- and t-trials during motor and verbal task training. In verbal task training, p- and t-trials are procedurally distinct and require dissimilar information processing activities. During p-trials, for example, items to be learned are shown to persons for study or encoding. During t-trials, these to-be-learned items are removed and persons are required to recall or retrieve them from memory. In motor task training, p- and t-trials are procedurally similar and require similar information processing activities. At p-trials, persons attempt to recall a to-be-learned movement from memory. This recall attempt is followed by knowledge of results (KR) regarding recall accuracy typically in visual or verbal form. At t-trials, persons are also required to recall the to-be-learned movement but KR is not provided. Thus, motor task training requires recall at the execution of both p- and t-trials, whereas verbal task training requires study at p-trials and recall at t-trials. Since study and recall processes have been found to differentially affect verbal acquisition and retention (e.g., Hogan & Kintsch, 1971; Wenger, Thompson & Bartling, 1980) it is necessary to create the same procedural environment in motor task training to examine their relative effects on motor acquisition and retention.

Another suggested reason for the differential effects of t-trial repetition on verbal and motor task performance stems from the difference in retention interval lengths used to investigate the retention of each type of task. The effects of repeated t-trial training on verbal task retention have been examined primarily using long-term retention intervals (e.g., Allen, et. al., 1969), whereas short-term retentions intervals typically have been used in examining t-trial effects on motor task retention (Duffy, et.al., 1975; Stelmach & Bassin, 1971). Because the

effect of repeated t-trials on motor task retention may vary with interval length as it does for verbal retention (Hogan & Kintsch, 1971; Thompson, et. al., 1978, Exp III; Wenger, Thompson & Bartling, 1980) meaningful comparisons between t-trial repetition effects on verbal and motor task retention have been difficult to make.

The present experiment examined the relative effectiveness of different motor training methods under acquisition and retention conditions similar to those used in verbal learning experiments. The general approach was to allow either repetition or alternation of p- and t-trials prior to a given t-trial during training and to compare the relative effects of this variation on both the acquisition and retention of motor skill.

Consistent with previous laboratory work, the motor task chosen for examination was linear positioning. Participants were required to move a sliding mechanism along a linear track and to learn and remember the end-location (final stopping position) of the movement performed. In order to create acquisition and retention conditions similar to those used in verbal task training, the present experiment differed from other motor task training experiments in three ways. First, training procedures were designed so that p-trials required study and t-trials required recall of movement end-location. This was accomplished by using an experimenter-defined movement procedure at p-trial execution and a learner-defined movement procedure at t-trial execution. Experimenter-defined p-trial movements were performed with the aid of a mechanical stop which was prepositioned by the experimenter along the linear track to define end-location. Participants moved the sliding mechanism along the track until contacting this stop. In doing so, they performed, and thereby studied, the actual movement end-location to be learned. Learner-defined t-trial movements, on the other hand, were performed with the mechanical stop removed. This ensured recall of the to-be-learned movement end-location from memory. Second, p- and t-trial training effects were measured over both short- and long-term retention intervals. This allowed for examination of the potential interaction between training method and retention interval length and permitted a more meaningful comparison of repeated t-trial training effects on verbal and motor retention. Third, training was restricted to the kinesthetic cue of end-location. Although multiple cues (such as distance, end-location and force) underlie the recall of positioning movements (Hagman & Williams, 1977; Gundry, 1975), training was restricted to the specific cue of end-location to prevent both the possibility of unsystematic participant selection of individual cues during training and the possibility that certain cues might react differently to p- and t-trial repetition because of their differential retention characteristics (Laabs, 1973; Posner, 1967).

Based on the results of recent research, predictions can be made regarding the relative effects of p- and t-trial training methods under the present experimental conditions. This research has examined the relative retention characteristics of learner-defined and experimenter-defined movement information (e.g., Kelso, 1977; Stelmach, Kelso & Wallace, 1975). The findings have been that both distance and end-location cues are better retained when generated under a learner-defined mode (with stop absent) than under an experimenter-defined mode (with stop present). This superior movement cue retention has been suggested to be caused by either (1) increased ability to preprogram efferent commands to the muscles, or (2) by more accurate coding of kinesthetic information under a learner-defined mode which allows prediction of distance and end-location prior to movement initiation and termination (Kelso, 1977; Stelmach, Kelso & Wallace, 1975).

Repetition of t-trials during training should force participants to rely more on learner-defined t-trial end-location than on experimenter-defined p-trial end-location for accurate recall. Because of the superior retention of learner-defined information, retention of end-location should be best when t-trials are repeated during training. In contrast, p-trial repetition should produce better acquisition than t-trial repetition because at p-trials learners receive more exposure to the correct end-location. Retention following p-trial repetition, however, should deteriorate rapidly because end-location was generated under experimenter-defined procedures.

The present hypothesis predicts a training method by experiment phase interaction with repeated p-trial training producing superior acquisition and repeated t-trial training producing superior retention of end-location information. Alternation of p- and t-trials during training should have an intermediate effect on both acquisition and retention. Partial support for this predicted interaction has been reported previously (Hagman, 1980) for movement distance information. The present experiment examined the generality of this prediction to movement end-location information. Separate investigation of end-location was prompted by previous findings that distance and end-location cues possess different retention characteristics (e.g., Laabs, 1973). Therefore, it was thought that end-location might react differently to p- and t-trial training method variations.

Method

Subjects

Forty-five governmental employees (33 men and 12 women) volunteered to serve as participants in the experiment. All were members of the professional and clerical staff of the Army Research Institute for the Behavioral and Social Sciences.

Apparatus

Movements were made from left to right using a metal slide which slid along a linear track consisting of two stainless steel rods 35 inches (88.90cm) in length. Two Thompson Ball Bushings supported the slide on the rods which were mounted in parallel on a metal frame 4.25 inches (11.00 cm) apart. The rods were located 11 inches (27.94 cm) above the base of the frame. The base rested on a standard table top 31 inches (78.74 cm) from the floor. A second slide was used to stop p-trial movements. This slide could be securely positioned by the experimenter along the entire length of the steel rods. A pointer attached to the experimenter's side of each sliding element ran along a meter stick calibrated in millimeters to indicate slide position. Additional apparatus included a chin rest to control head movements and body position; earphones through which participants heard tape-recorded procedural instructions; and a blindfold to prevent participants from using visual cues during the experiment.

Design

The experiment contained an acquisition and a retention segment as shown in Figure 1. The acquisition segment consisted of 18 training trials divided into three cycles of six trials each. Each cycle contained p- and t-trials. P-trials were experimenter-defined movements during which participants contacted the mechanical stop which defined the movement end-location to be learned and remembered. T-trials were learner-defined movements during which participants attempted to recall (reproduce) the studied end-location with the stop removed. The sequence of p- and t-trials within cycles differed for each of three training groups. For Group STANDARD, a cycle consisted of three p- and three t-trials administered in an alternating sequence. For Group PRESENTATION, the first five trials of each cycle were p-trials and the sixth was a t-trial. For Group TEST, the first trial was a p-trial and the next five were t-trials. Training was such that a t-trial occurred every sixth trial for all three groups. As a result, a 3 x 3 mixed factorial design was used to examine acquisition performance with the between-subjects variable being Groups (STANDARD, PRESENTATION, TEST) and the within-subjects variable being Trials (6, 12, 18).

The retention segment of the experiment consisted of a single t-trial performed at both 3 minutes and 24 hours after Trial 18 of acquisition. Performance at Trial 18 was used to evaluate immediate recall accuracy and incorporated into a 3 x 3 mixed factorial design used to analyze retention. In this design, the between-subjects variable was Groups (STANDARD, PRESENTATION, TEST) and the within-subjects variable was Time of Recall (Immediate, 3 minutes, 24 hours). Fifteen participants were assigned randomly to each of the three groups with the constraint that each group contained the same number of men and women.

	ACQUISITION																		RETENTION	
	TRIALS																			
	CYCLE 1						CYCLE 2						CYCLE 3							
GROUP	1	2	3	4	5	6/	/7	8	9	10	11	12/	/13	14	15	16	17	18	3 MIN	24 HR
STANDARD	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	T	T
TEST	P	T	T	T	T	T	P	T	T	T	T	T	P	T	T	T	T	T	T	T
PRESENTATION	P	P	P	P	P	T	P	P	P	P	P	T	P	P	P	P	P	T	T	T

FIGURE 1. TRIAL SEQUENCE FOR EACH GROUP AT ACQUISITION AND RETENTION.

Procedure

At the beginning of the experiment, participants were instructed to learn and remember end-location. They were shown a written copy of the entire p- and t-trial command sequence appropriate to their training group and told the meaning of each command that they would be hearing. The p-trial command was "Movement" and the t-trial command was "Recall Movement." Each of these commands were preceded by "Ready" and followed by "Rest." At "Ready" the experimenter grasped the participant's right hand and placed it on the handle of the slide. Five seconds later, participants heard either "Movement" or "Recall Movement" depending on their training group. At the "Movement" command, they moved the slide across the track at a moderate pace until contacting the stop. At the "Recall Movement" command, participants moved the slide along until they felt that they had moved it to the correct end-location. Five seconds were allowed for execution of p- and t-trial movements. During this interval, white noise was delivered through the earphones to eliminate auditory cues resulting from displacement of the slide. "Rest" marked the start of a 10 second time interval during which participants removed their hand from the slide and placed it in a predetermined resting place on the table. During rest periods the experimenter recorded recall accuracy to the nearest millimeter and repositioned either the slide alone or both it and the mechanical stop in preparation for the next trial. After "Rest," participants heard "Ready" and the sequence of commands for the next trial began. During the retention segment of the experiment, intervals of 3 minutes and 24 hours were inserted between "Rest" and "Ready." Participants were asked not to count while moving the slide and shown the approximate movement speed (125 mm/sec) desired by the experimenter. Prior to making the first movement, participants donned their blindfold and earphones and were given an opportunity to move the slide to get a feel for its basic movement characteristics.

Results

Algebraic (signed) and absolute (unsigned) error scores were recorded for each t-trial performed during the acquisition and retention segments of the experiment. Algebraic error was used to reveal the direction (i.e., overshooting versus undershooting of the criterion) of recall error, whereas absolute error was used to reveal recall error without respect to direction. Each performance measure was analyzed separately.

Acquisition

Mean algebraic and absolute error scores for acquisition t-trials are shown on the left in Figures 2 and 3. Initial statistical analyses were restricted to the scores on those t-trials which coincided temporally for all three training groups, i.e., Trials 6, 12, and 18. These scores were analyzed using a Groups (STANDARD, PRESENTATION, TEST) by Trials (6, 12, 18) mixed factorial analysis of variance.

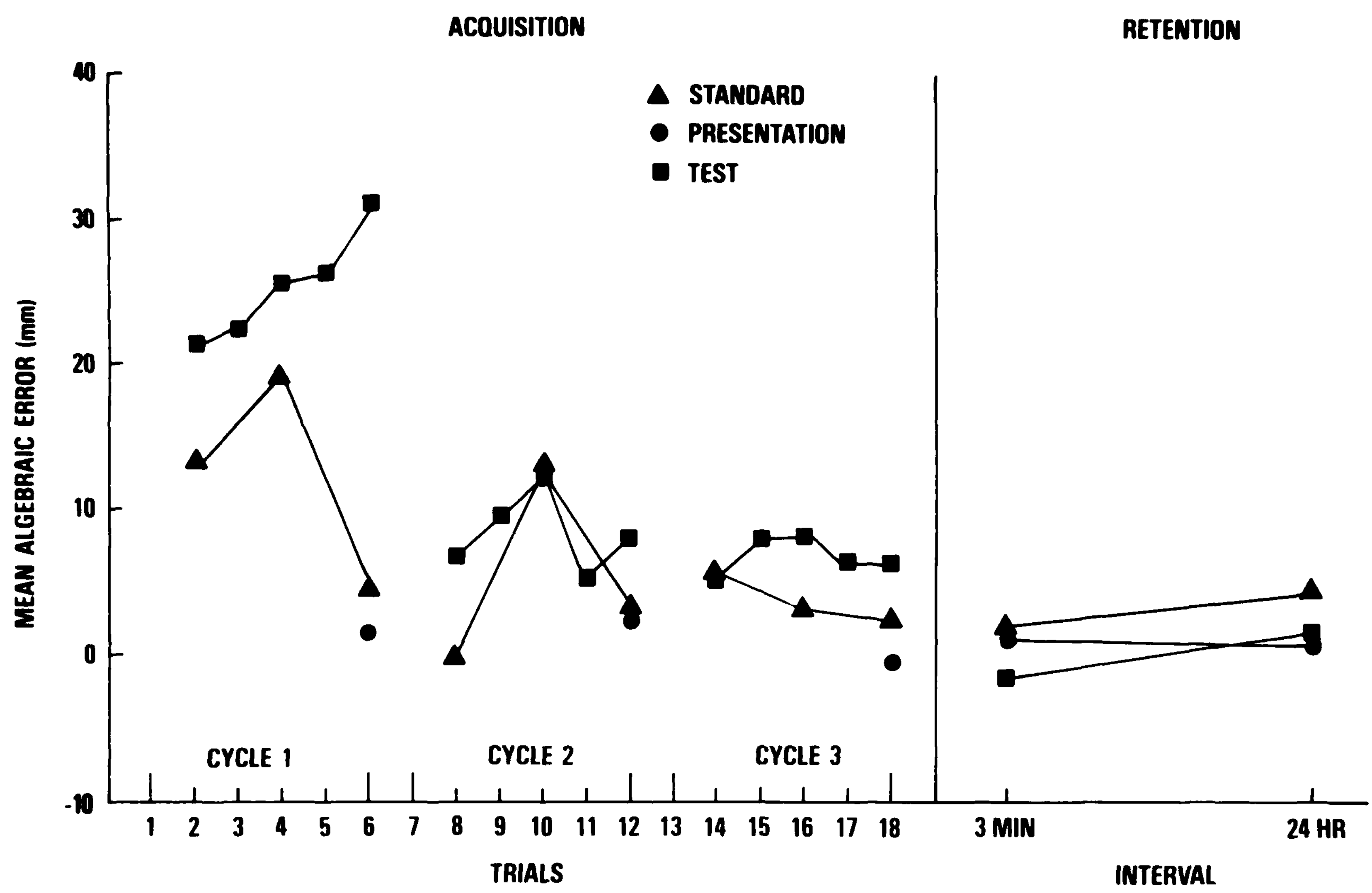

Figure 2. Mean t-trial algebraic error for the STANDARD, PRESENTATION and TEST training groups at acquisition and retention.

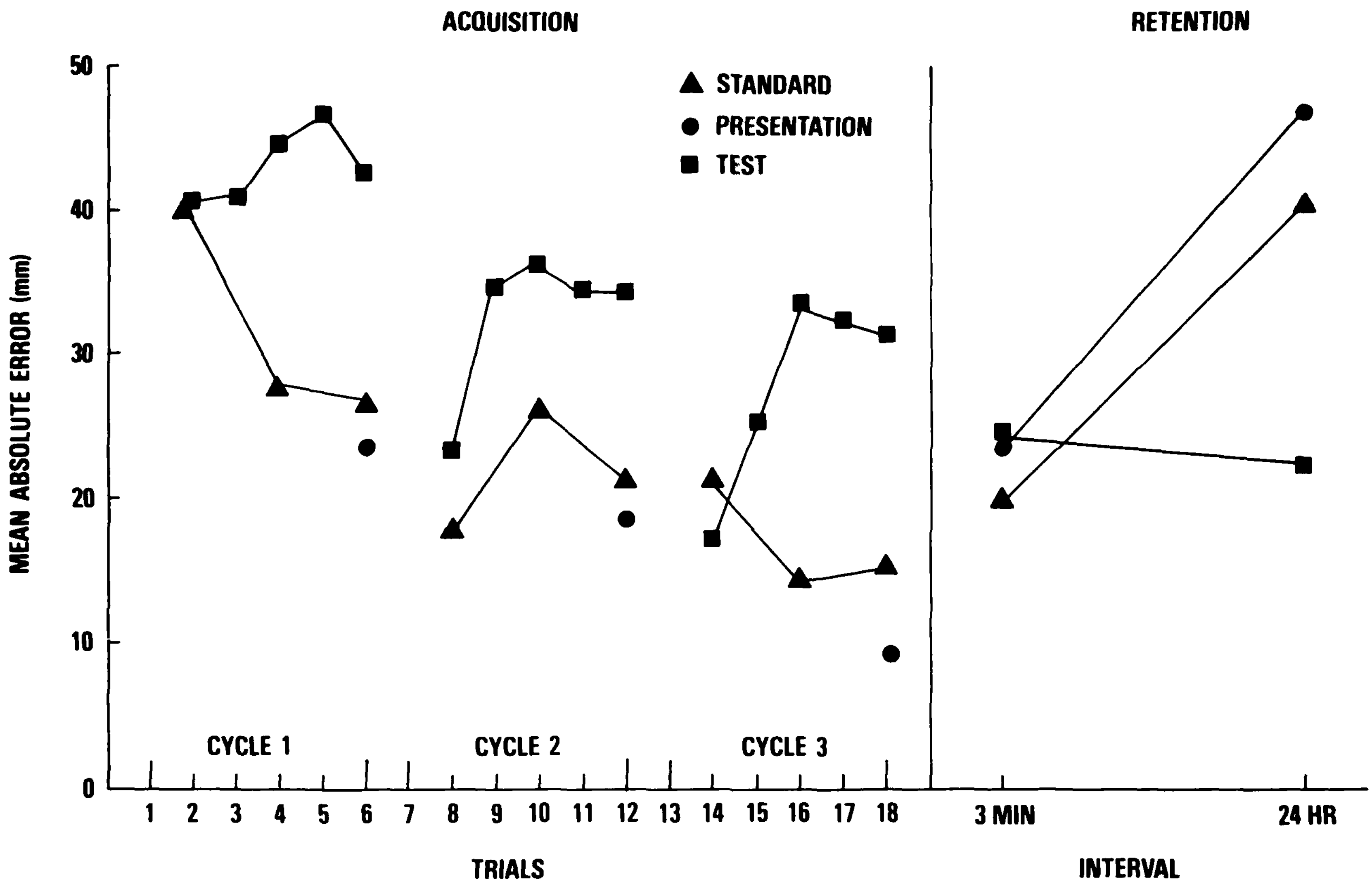

Figure 3. Mean t-trial absolute error for the STANDARD, PRESENTATION and TEST training groups at acquisition and retention.

Analysis of algebraic error revealed no significant main effects or interactions. The rejection region for this and all future analyses was .05. Although there were no differences between groups, visual inspection of Figure 2 suggested an increase in error for the TEST group across trials within Cycle 1 but not within Cycles 2 and 3. A subsequent Cycle (1-3) by Trials (1-5) analysis of variance, however, performed on all t-trial scores for the TEST group showed this observation to be unreliable although the overall cycles effect did approach significance $F\ (2,28) = 2.65$, $.05 < p < .10$. Thus, it can be concluded that algebraic error at acquisition did not differ as a function of training method.

Training method variation did affect absolute error, as shown in Figure 3. An analysis of variance revealed significant main effects of Trials, $F\ (2,84) = 6.16$, and Groups, $F\ (2,42) = 8.07$ with no significant interaction. Individual comparisons by the least significant difference (LSD) method (Carmer & Swanson, 1973) revealed that the groups effect resulted from the TEST group displaying greater error than either the STANDARD, $LSD\ (42) = 14.62$, or PRESENTATION group, $LSD\ (42) = 18.71$, whereas error for these latter two groups did not differ significantly. Thus, p-trial repetition and p- and t-trial alternation during training produced better acquisition performance than t-trial repetition during training. Because TEST and STANDARD group performance was almost identical at Trial 2 (the first t-trial), the inferior acquisition performance of the TEST group at the end of each training cycle cannot be attributed to differences among groups present at the start of training. Unfortunately, PRESENTATION group performance at Trial 2 could not be measured because of the training trial sequence used. However, one can be reasonably confident that its performance level at the start of training was comparable to that of the other groups based on the relatively homogeneous participant sample and the random allocation of participants to groups.

Inspection of TEST group performance at all t-trials revealed a serrated acquisition curve typified by alternation of increased error within-cycles followed by decreased error between-cycles. To determine the reliability of the within-cycle changes, a Cycle (1-3) by Trials (1-5) analysis of variance was performed on all TEST group t-trial scores. As expected, the Trials effect was significant, $F\ (4,56) = 5.28$ as was the Cycles effect, $F\ (2,28) = 3.83$. Individual comparisons showed a decrease in error from Cycle 1 to 2 but not from Cycle 2 to 3. The trials effect was the result of error being greater on the last four t-trials of each cycle than on the first t-trial of each cycle. This increase in error across repeated t-trials is consistent with the results of previous motor (Duffy, et.al., 1975; Hagman, 1980) and verbal learning studies (e.g., Bregman & Wiener, 1970) using repeated t-trials during training.

To examine the decrease in error between cycles, group performance was compared before within-cycle error had a chance to develop for the TEST group. This required an additional Groups by Trials analysis of variance in which STANDARD and PRESENTATION group error at the end of

each cycle, i.e., Trials 6, 12, and 18 was compared with TEST group error at the beginning of each cycle, i.e. Trials 2, 8, and 14. Although the trials effect was still significant with this analysis, $\underline{F}$ (2,84) = 13.83, the groups effect was not. The lack of a groups effect indicated that between-cycle error decreases offset the significant increase in error found within-cycles. Thus, TEST group error was greater than that of the other groups only after within-cycle error had a chance to increase with t-trial repetition. From the preceeding analyses, it can be concluded that t-trial repetition during training produced both positive and negative effects on acquisition. The negative effects took the form of increased within-cycle error,while the positive effects took the form of decreased between-cycle error. Both of these effects are consistent with the findings of previous verbal (e.g., Izawa, 1970; Tulving, 1967) and motor learning experiments (Hagman, 1980).

Retention

Mean algebraic and absolute error scores obtained during the retention phase of the experiment are shown on the right side of Figures 2 and 3. Retention was examined using a Groups (STANDARD, PRESENTATION, TEST) by Retention Interval (Immediate, 3 minutes, 24 hours) analysis of variance. Performance at Trial 18 was included in the analysis to indicate immediate recall at the end of acquisition.

Consistent with the findings for acquisition, no significant retention effects were found using algebraic error. In contrast, absolute error revealed a significant main effect of Retention Interval, $\underline{F}$ (2,84) = 12.53, and a Retention Interval by Group interaction, $\underline{F}$ (4,84) = 7.03. Further analyses were restricted to examination of the interaction effect. As shown in Figure 3, the interaction resulted from an increase in error across retention intervals for the STANDARD and PRESENTATION groups and a decrease in error for the TEST group. Individual comparisons of simple main effects showed that at the end of acquisition (Trial 18) the TEST group displayed greater error than either the STANDARD, <u>LSD</u> (84) = 15.53 or the PRESENTATION group, <u>LSD</u> (84) = 21.73, and that no differences existed between the error scores of the latter two groups (i.e. TEST > PRESENTATION = STANDARD). Three minutes after acquisition, the only significant change in group performance was an increase in error for the PRESENTATION group, <u>LSD</u> (84) = 13.93. Although visual inspection of the retention scores suggests an increase in error for the STANDARD group and a decrease in error for the TEST group over the 3 minute retention interval, both performance changes were nonsignificant. As a result of these numerical changes, however, no differences in error were found among the three groups 3 minutes after acquisition (i.e., TEST = PRESENTATION = STANDARD). Between 3 minutes and 24 hours after training, error increased significantly for both the PRESENTATION and the STANDARD groups with <u>LSD</u> (84) = 23.47 and 20.53 for each group, respectively. In contrast, TEST group error did not change significantly over this same time interval. As a result, 24 hours after acquisition TEST group error was less than that of the STANDARD, <u>LSD</u> (84) = 18.2,

and the PRESENTATION group, LSD (84) = 24.8, whereas the error for these latter two groups did not differ significantly (i.e., STANDARD = PRESENTATION > TEST). Thus, emphasis on p-trial repetition or p- and t-trial alternation during training resulted in rapid and extensive forgetting, whereas t-trial repetition during training prevented forgetting from occuring. These results show the benefit of examining training method effects over both short- and long-term retention intervals.

DISCUSSION

The three motor task training methods examined in the present experiment produced differential acquisition and retention performance in terms of absolute error. Performance at acquisition improved in the usual negatively accelerated manner when training emphasized p-trial repetition or p- and t-trial alternation with both methods being equally effective. When training emphasized t-trial repetition, acquisition performance was irregular and characterized by increased within-cycle error followed by decreased between-cycle error. Because of the irregular nature of the TEST group's performance, differences among groups did not occur uniformly throughout acquisition and the relative superiority of the three training methods depended on where performance was compared during acquisition. When comparisons were made before within-cycle t-trial repetition inflated TEST group error, no performance differences were found among the three groups. When comparisons were made after the TEST group had completed t-trial repetition within-cycles, the groups performing p-trial repetition and p- and t-trial alternation displayed superior acquisition performance. This was the case at the end of training.

Of particular interest was the question of why t-trial repetition produced both increased within-cycle error and decreased between-cycle error. Within-cycle error could have occurred for at least two reasons. First, participants may have been attempting to reproduce an ever decaying memorial representation of movement end-location established during prior p-trial execution. As the time interval between p- and t-trial execution increased with successive t-trial repetitions, recall got progressively worse. Although a decay interpretation is consistent with earlier research findings for distance information (Hagman, 1980), its validity for end-location information appears low in that end-location is relatively resistent to decay (e.g., Laabs, 1973). A second and more probable explanation is that within-cycle error increased due to interference produced by t-trial repetition. Although t-trials were not intended to interfere with acquisition, their end-location usually was different than that of the criterion end-location due to inaccurate participant recall. Because of the difference between recalled end-location and criterion end-location, t-trials possessed the potential for producing interference (Craft & Hinrichs, 1971; Patrick, 1971; Hagman, 1978). Thus, increased within-cycle error could have been caused by interfering movements occuring at t-trial repetition. This notion also receives indirect support from the results of verbal task learning studies showing

that prior recall can interfere with subsequent recall (e.g. Roediger & Schmidt, 1980). One potential way of reducing the within-cycle error increases would be to introduce verbal KR regarding error direction and magnitude after each t-trial. Such a method might both improve acquisition by reducing within-cycle error increases and maintain the superior retention benefits associated with a repeated testing strategy. Future research will be directed toward examination of this issue.

Reasons why t-trial repetition produced such large between-cycle error decreases during acquisition are not readily apparent. Verbal researchers have suggested that one function of testing via recall is to enhance a person's ability to recognize past words recalled (Klee & Gardiner, 1976). Perhaps, the same effect of testing via t-trials occurs for motor tasks. After repeated t-trial attempts, persons may know more about their recall performance than persons who do not perform repeated t-trials. If this notion is correct, participants in the TEST group may have been better able to discriminate their recalled end-location from that of the criterion end-location, and thus, may have been more capable of making the appropriate adjustments needed to improve accuracy. Although speculative, the notion that t-trial repetition improves discrimination ability is consistent with previous motor research findings (Newell, 1974). In essence, t-trial repetition may serve to potentiate, or increase, the effectiveness of subsequent p-trial execution. Although this type of potentiation has been reported to occur in verbal task learning (Izawa, 1970) it has only been hinted at in motor task learning (Bilodeau & Bilodeau, 1958; Hagman, 1980; Henderson, 1977). Clearly, more research is needed before a firm conclusion can be made regarding the potentiating effects of t-trial repetition in motor task learning. One approach suggested earlier (Hagman, 1980) would be to vary the number of t-trials repeated prior to p-trial execution. If potentiation does occur, one should find that increased prior t-trial repetition improves performance following a subsequent p-trial.

Differential effects of training method were also evident at retention testing. Forgetting was rapid and extensive when p-trials were repeated and when p- and t-trials were alternated during training. In contrast, t-trial repetition prevented forgetting and produced better relative long-term retention than either of the other two training methods. An answer to the question of why t-trial repetition promotes long-term retention relies on the distinction between experimenter-defined and learner-defined movements and the types of information available to persons under each movement mode. In an experimenter-defined mode, where end-location is not known prior to movement termination, persons base their recall on kinesthetic information originating from muscles and joints (Goodwin, McCloskey & Matthews, 1972; Marteniuk & Roy, 1972. In a learner-defined mode, where end-location can be predicted prior to movement initiation or termination, persons are able to rely not only on kinesthetic cues but also on efferent commands to the muscles (Jones, 1974). This creates the possibility of preprogramming of movement end-location (Stelmach, et. al., 1975) and implies a greater involvement of central rather than peripheral mechanisms in movement reproduction.

Prediction of movement end-location might also promote coding of kinesthetic information. This could occur under a corollary discharge process (Sperry, 1950; Teuber, 1974), where cortical sensory centers are preset prior to movement initiation to improve reception of kinesthetic information. Opportunities for preprogramming and more effective kinesthetic coding have both been suggested to explain superiority of learner-defined movement retention (e.g., Kelso, 1977; Stelmach, et. al., 1975).

In the present experiment, repeated t-trial execution during training may have produced superior long-term retention because t-trials were learner-defined. Emphasis on t-trials during training forced participants to rely on retention of their t-trial recall performance rather than their p-trial study performance to support later recall attempts. In contrast, p-trial repetition during training may have forced participants to rely more on experimenter-defined information which is forgotten rapidly over time. Consistent with the above interpretation, p- and t-trial alternation during training should have produced effects intermediate to those found for p-trial repetition and t-trial repetition. This was found although the effects were not significant. Support for this notion, however, has been reported in an earlier experiment examining retention of movement distance information (Hagman, 1980).

Other interpretations could also be offered to account for the present results. First, one could argue that movement retention is based primarily on retrieval of memorial information. T-trial repetition gave participants an opportunity to practice and improve retrieval, and thereby eliminated or reduced long-term retention losses due to ineffective retrieval. This interpretation receives some support from verbal learning studies showing that subjects can learn to improve their retrieval (Halff, 1977). Also, the findings of hypermnesia (the increase of recall over repeated recall trials) using pictured materials (e.g., Erdelyi, Bischke & Finkelstein, 1977) support this argument. Second, it could be argued that more elaborate coding of movement information occurs under conditions of t-trial interference during acquisition and this facilitates both retention and transfer. In the present experiment, repeated t-trials produced interference during acquisition and may have improved the coding of end-location at p-trial execution. This argument, although somewhat more formalized elsewhere (Battig, 1979) is not unlike the potentiation interpretation suggested earlier. Lastly, it could be suggested that added variety of movement per se under t-trial repetition improved retention because of enhanced schema development. The schema is an abstraction of movement characteristics which develops over practice as a function of variability during training (e.g., Schmidt, 1975), and its strength is postulated to directly affect retention and transfer. In the present experiment, variability was highest under a t-trial repetition method because participants were inaccurate in their recall This variability may have caused the superior retention. A simple experiment could be conducted to distinquish between the variabality interpretation and the earlier interpretation of the results based on the distinction between experimenter-defined and learner-defined movements.

This experiment would compare task retention of the t-trial repetition group with that of another group yoked to the t-trial repetition group's recall performance. The yoked group would perform experimenter-defined p-trial movements identical to the learner-defined t-trial movements performed by the t-trial repetition group. Under this procedure both groups would receive the same movement variability during training but would differ as to the movement mode (learner-defined versus experimenter-defined) under which it was generated. If the t-trial repetition group is superior to the yoked group, then support would be provided for the notion that learner-defined movements are easier to remember than experimenter-defined movements for movement variability would be identical for each group. Future experiments will examine this issue.

CONCLUSIONS

Results of the present experiment reveal the relative effects of presentation and testing on motor task acquisition and retention. In doing so, they address the Army's question of which specific training methods effectively promote the highest levels of motor skill proficiency. It can be concluded that:

(1) Final acquisition performance is better when training emphasizes either repeated presentation or alternation of presentation and testing rather than repeated testing;

(2) The primary benefit of repeated testing during training is enhanced long-term retention. Relative to other training methods, long-term retention of motor skill is improved substantially by a training method which emphasizes repeated testing. Thus, testing during training not only demonstrates what has been learned during presentation but also contributes to learning and retention processes;

(3) The retention benefits derived from repeated testing can be achieved by changing the emphasis of training from presentation to testing. This could be done without the negative aspects of additional expenditures in time, money and personnel;

(4) The effect of presentation and testing during training is similar for both verbal and motor tasks. This is true when presentation and testing procedures employed during training are similar for both kinds of tasks;

(5) Future research should be directed toward determining; (a) the specific reason or reasons why t-trial repetition during training enhances retention, and (b) whether the benefits of repeated testing found in the laboratory will generalize to military-related tasks. Of particular interest should be the investigation of procedural tasks. These tasks require execution of successive simple motor movements in a serial fashion and are characteristic of many motor tasks performed within the Army.

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